

Presented at the Workshop on Chiral Dynamics,
Massachusetts Institute of Technology, July 1994
Tel Aviv U. Preprint TAUP 2207-94
Bulletin Board: hep-ph@xxx.lanl.gov/9410215

Pion Polarizability, Radiative Transitions, and Quark Gluon Plasma Signatures

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Abstract

Can one expect gamma rays rates from the QGP to be higher than from the hot hadronic gas phase? Xiong, Shuryak, Brown (XSB) calculate photon production from a hot hadronic gas via the reaction $\pi^- + \rho^0 \rightarrow \pi^- + \gamma$. They assume that this reaction proceeds through the $a_1(1260)$. They also use their estimated a_1 radiative width to calculate the pion polarizability; following a connection noted previously by Holstein. However, for $a_1(1260) \rightarrow \pi\gamma$, the experimental radiative width is more than two times less than the value 1.4 MeV estimated and used by XSB. We describe how the gamma production reaction can be studied in Fermilab E781 (via the inverse reaction, with detailed balance) via the Primakoff reaction $\pi^- + \gamma \rightarrow \pi^- + \rho^0$. Such a study can provide the data base for evaluations of the utility of gamma production experiments in QGP searches. One can experimentally check the a_1 dominance assumption of XSB. A remeasurement of the $a_1(1260)$ radiative width and of the pion polarizability in Fermilab E781 will also allow us to reevaluate the consistency of their expected relationship.

Chakrabarty et al. [1] studied the expected gamma ray yields from hot hadronic gases and the QGP. They suggested that gamma rays between 2-3 GeV from the QGP outshine those from the hot hadronic gas phase. One expects many gamma rays from QGP processes, such as a quark-antiquark annihilation $q\bar{q} \rightarrow g\gamma$ or Compton processes such as $qg \rightarrow q\gamma$ and $\bar{q}g \rightarrow \bar{q}\gamma$. Xiong, Shuryak, Brown (XSB) [2] studied gamma-ray production from a hot hadronic gas. They calculate photon production (above 0.7 GeV) via the reaction $\pi^- + \rho^0 \rightarrow \pi^- + \gamma$. They assume that this reaction proceeds through the $a_1(1260)$. A more recent photon production calculation also involving the a_1 resonance was given by Song [3]. In a hadronic gas at high temperature, the $\pi\rho$ interaction can be near the a_1 resonance [2]. One must consider also that certain properties (masses, sizes, parity mixing) of the π and ρ and a_1 change [2, 3, 4, 5, 6], and that their numbers increase due to the Boltzmann factor. XSB expect an increased yield from the hot hadronic gas, higher than estimated previously by Kapusta et al. [7]. There are many other theoretical studies for gamma rays from hadronic gas and QGP in the Quark Matter conferences, and elsewhere. Some relevant articles are by Ruuskanen [8], Kapusta et al. [9], Alam et al. [10], Nadeau [11], and Schukraft [12].

We consider an experimental determination of the $\pi^- + \rho^0 \rightarrow \pi^- + \gamma$ total reaction rate for photon production above 0.7 GeV. The gamma production reaction can be studied (via the inverse reaction, with detailed balance) via the Primakoff reaction $\pi^- + \gamma \rightarrow \pi^- + \rho^0$. Here, the reaction takes place when an incident high energy pion interacts with a virtual photon in the Coulomb field of a target nucleus of atomic number Z . Such a study measures the reaction rate for normal mass pion and rho and intermediate resonances at normal temperatures. It therefore experimentally provides the data base for evaluations of the utility of gamma production experiments in QGP searches. One can experimentally check the a_1 dominance assumption of XSB. The invariant mass of the produced $\pi\rho$ system is a signature for the reaction mechanism. For the case of $\pi\rho$ detection, one may expect the invariant mass to show a spectrum of resonances that have a $\pi\rho$ decay branch. These include the $a_1(1260)$, $\pi(1300)$, $a_2(1320)$, $a_1(1550)$, etc.

High energy pion experiments at FNAL E781 [13, 14] and CERN can obtain new high statistics data for radiative transitions leading from the pion to the $a_1(1260)$, and to other resonances; via detection of the $\pi^-\rho^0$ final state. These radiative transition widths are predicted by vector dominance and quark models. They were studied in the past by different groups, but independent data would still be of value. For $a_1(1260) \rightarrow \pi\gamma$, the experimental radiative width given [15] is $\Gamma = 0.64 \pm 0.25$ MeV; more than two times less than the value 1.4 MeV estimated by XSB. It is with the 1.4 MeV width that XSB calculate the high energy photon production cross section.

XSB also use their estimated a_1 radiative width to calculate the pion polarizability, obtaining $\alpha_\pi = 1.8 \times 10^{-43}$ cm³. The connection between this width and the polarizability was previously noted by Holstein [16]. He showed that meson exchange via a pole diagram involving the a_1 resonance provides the main contribution (2.6×10^{-43} cm³) to the polarizability.

The Fermilab E781 experiment can obtain data for pion polarizability and the a_1 radiative transition [14]. A remeasurement of the $a_1(1260)$ width and of the pion polarizability will allow us to reevaluate the consistency of their expected relationship. In addition, E781 can study the reaction $\pi^- + \rho^0 \rightarrow \pi^- + \gamma$, a background reaction of importance in quark gluon plasma studies.

This work was supported by the U.S.-Israel Binational Science Foundation, Jerusalem, Israel.

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